A Vision Center of Excellence review of noteworthy clinical and research reports and topics from diverse fields within vision care.

FRONTLINES OF EYE CARE

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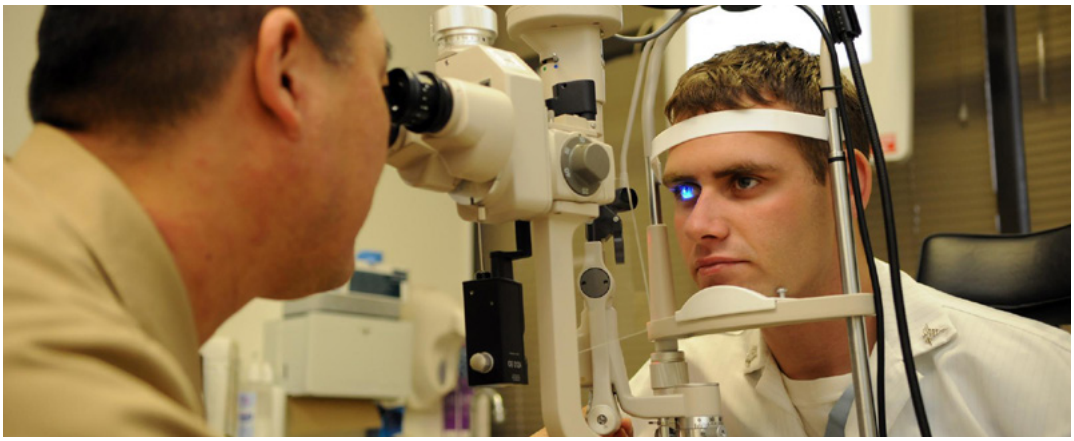
FEATURE

KERATOCONUS AND CORNEAL CROSS-LINKING



Keratoconus is a bilateral, asymmetric and progressive disease in which the normally round, dome-like cornea becomes thin and can develop a cone-like bulge. This abnormal and distorted shape prevents light from focusing correctly on the retina causing blurring, vision distortion, increased nearsightedness or astigmatism, halos, eye strain, headaches, eye irritation and increased sensitivity to glare and light. Keratoconus typically presents in the second to third decade of life but can start as early as the first and is estimated to occur in 1 out of every 1,500 to 2,000 people.[1,2] Treatments for keratoconus depend on the severity of the symptoms and through discussions with the treating physician, the patient's preference. In the earliest stages, glasses or soft and rigid gas permeable contact lenses may be used to correct the nearsightedness and astigmatism. Additionally, the resurgence of scleral contact lenses has become an option for vision correction given their ability to improve keratoconus-related vision distortion.[3] Intracorneal ring segments (e.g., Intacs®) are another treatment option and work by elevating the peripheral corneal tissue to normalize the overall corneal shape and curvature. Corneal surgery may become necessary in individuals who become intolerant to contact lenses or intracorneal ring segments.[4] Historically, the only surgical option was full thickness corneal transplant from human donor tissue, which has a variety of risks including but not limited to tissue transplant rejection, infection and inflammation and a structurally weak graft-donor interface.[5] In the military, however, such treatments may significantly limit activities and assignments, and may lead to medical disqualification from military specialties or medical discharge.

For Service members, combat requires optimal vision and therefore, keratoconus is an operationally-important diagnosis that carries a number of mission-relevant consequences. Additionally, the rise in sophisticated battlefield technology reliant on vision (e.g., computer screens), creates an environment in which Service members are increasingly dependent upon maintaining vigilance in their visual processing. Even as body armor technology has improved, the eyes still remain exquisitely vulnerable because of the need to maintain clear

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and alert vision. Anything that degrades vision (e.g., keratoconus) or is perceived by the Service member to degrade their vision is a disadvantage and may impact force readiness and the ability to effectively fight. Consequently, the military is keenly interested in, and continually follows the progress of novel treatment options that stabilize vision early in the course of keratoconus, theoretically before the patient reaches the point of needing more advanced contact lens or surgical interventions. Corneal collagen cross-linking (CXL) is a procedure that uses ultraviolet-A light in combination with riboflavin (vitamin B2) to halt the progression of keratoconus. CXL works by increasing collagen cross-links in the cornea, strengthening and "stiffening" the

> *"The military is keenly interested in, and continually follows the progress of novel treatment options that stabilize vision early in the course of keratoconus."*

cornea and preventing it from progressively weakening and distorting, thereby limiting deterioration of vision.[6] CXL has also been used in combination with intracorneal ring segments to stabilize the cornea and, in some cases, to re-gain lost vision.[4] There are a number of ongoing clinical trials both in the U.S. and abroad to establish the efficacy of CXL as a treatment option for keratoconus. While the CXL procedure is currently under investigation and not FDA-approved in the U.S., promising results from international studies indicate that CXL treatments halt the progression of keratoconus by increasing the stability of the cornea, resulting in corneal flattening and improved vision.[7] Long-term stability, safety and efficacy of CXL are unclear and are of particular importance to the military, and remain the subjects of further investigation. For now, CXL remains an unapproved treatment in the U.S. and unauthorized in the U.S. military. Furthermore, FDA approval does not guarantee automatic acceptance within DoD.

NEWS FROM VCE

ASSISTANT SECRETARY OF DEFENSE FOR HEALTH AFFAIRS (ASD/HA) DR. JONATHAN WOODSON SIGNS "TREATMENT OF TRAUMATIC EYE INJURIES" MEMORANDUM

Due in large part to the efforts of individuals and organizations across the Defense Department (DoD), including the Joint Trauma System (JTS), the Defense Health Agency Medical Logistics Division (DHA MEDLOG), the Committee on Tactical Combat Casualty Care (CoTC3), DHA Force Health Protection and Readiness (FHP&R) and VCE, on July 7, 2014 the ASD/HA signed a DoD-wide memorandum titled "Treatment of Traumatic Eye Injuries." This memo outlines that the Services and Joint Staff must review and update their doctrine and training to reflect: (1) the current guidance from the JTS Clinical Practice Guideline (CPG) titled the "Initial Care of Ocular and Adnexal Injuries[1]"; (2) Tactical Combat Casualty Care (TC3) Guidelines[2]; and (3) VCE recommendations, all of which stress the use of a rigid eye shield at the point of injury and immediate evacuation to ophthalmology as the proper first response in the management of ocular trauma. This memo, along with the JTS CPG and TC3 Guidelines, is now being disseminated to the Service policy points of contact for distribution to the Force, to include the Joint Staff. Illustrating the need for this measure, a prior JTS study revealed that only approximately 40 percent of eye injuries were treated with rigid eye shields at the time of injury.[3] Additionally, an in-depth evaluation of root causes revealed the widespread continued fielding and use of antiquated military "Eye Trauma" first aid kits that promoted the incorrect treatment of ocular injuries – eye patching. These kits, dating from the early 1960s, are commonly found as components of larger military and civilian first aid kits, such as those found in vehicles and boats.

DHA MEDLOG has been working to remove and destroy the obsolete eye trauma first aid kits from all military first aid kits (FAKs). Of note, on July 22, 2014, a formal DoD Medical Materiel Quality Control Message (MMQC-14-1652)[4] was issued to the Services to destroy these outdated supplies and replace them with the rigid eye shields in FAKs.

Separately but additionally, the versatile cravat, or triangular bandage—which is also commonly found in these and other first aid kits— should NEVER be placed over the eye in the event of ocular trauma, despite enclosed instructions to do so, unless the eye is first properly protected with a rigid shield.

These important strides taken by the DoD can be used to influence proper eye trauma training and management in the military as well as the broader civilian community, including emergency medicine and community-based first aid courses (e.g., schools, scouting, civic organizations). VCE will continue to work alongside both military and civilian organizations to ensure that only evidence-based management and equipment is used in the event of ocular trauma. These efforts will improve and standardize care for Service members, as well as promote the implementation of best practices in care across the DoD, VA and civilian communities.

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For individuals who want to enlist in the Services, keratoconus of any degree remains a physical disqualifier for entrance according to Department of Defense (DoD) Instruction on Medical Standards for Appointment, Enlistment, or Induction in the Military Services (DoDI 6130.03, Section 4c).[8] Those who are diagnosed with keratoconus and undergo corneal surgery or corneal transplant are still not eligible for enlistment. Additionally, incisional surgery of any kind, including, but not limited to, partial or full thickness corneal transplant, radial keratotomy (RK), astigmatic keratotomy (AK) or corneal implants (Intacs®)" disqualifies individuals from active military service. If an active duty Service member were to develop keratoconus, continuing military service would depend on the severity of the symptoms, treatment required and individual duties and military specialties. Some cases stabilize and are readily corrected with contact lenses; however, both the DoD policy DA PAM 40-506 (The Army Vision Conservation and Readiness Program)[9] and the U.S. CENTCOM 021922Z POLICY (December 2011 MOD ELEVEN TO U.S. CENTCOM INDIVIDUAL PROTECTION AND INDIVIDUAL-UNIT DEPLOYMENT)[10] strictly prohibit contact lens wear during basic training, field exercises, gas chamber exercises, deployments and/or combat with the exception of select aircrew (e.g., Army and Air Force helicopter pilots) who have written authorization to wear contact lenses in their Area of Responsibility or theater).[9] The military may still medically discharge an active duty Service member if symptoms and the condition progress to a point at which duty is impaired or corneal surgery is required.

> *"The long-term results on future corneal health for patients who undergo CXL early in life remain unknown; therefore, further clinical investigation would greatly benefit individuals with keratoconus."*

BRIEF REVIEW

PORCINE MODEL TO STUDY PRIMARY OCULAR TRAUMA FOLLOWING BLAST OVERPRESSURE

Sherwood, D., Sponsel, W.E., Lund, B.J., Gray, W., Watson, R., Groth, S.L., Thoe, K., Glickman, R.D., Reilly, M.A. (2014). Anatomical manifestations of primary blast ocular trauma observed in a post-mortem porcine model. Invest Ophthalmol Vis Sc., 55, 1124-1132.
http://www.ncbi.nlm.nih.gov/pubmed/?term=24474279

A recent Institute of Medicine report (Gulf War and Health, Volume 9: Long-Term Effects of Blast Exposures, National Academies Press, 2014) acknowledged that there was sufficient evidence to link blast exposure with penetrating globe injuries, but that there was insufficient evidence of an association between blast exposure and long-term ocular effects in cases of acute non-penetrating ocular injury. Because it is not possible to conduct controlled studies using humans, researchers rely on animal models to investigate the effects of blast exposure. There is a particular need for more studies and a better understanding of isolated primary blast-related ocular injuries, which are defined as those caused by blast overpressure waves (shock waves), or the instantaneous rise in pressure as the shock wave passes through the body at supersonic speeds.

In their recent article, "Anatomical manifestations of primary blast ocular trauma observed in a postmortem porcine model," Sherwood and colleagues report the use of a postmortem porcine blast model for evaluating non-penetrating, closed-globe injuries following blast exposure using a shock tube. The shock tube produces a Friedlander-style pressure wave that is similar to the low end pressure waves produced by improvised explosive devices, thereby giving validity to the shock tube model of primary blast. Inflated pig cadaver globes (10 to 20 mmHg) were initially examined by B-scan and biomicroscopy ultrasonography for preexisting pathology: approximately 10 percent of samples were excluded from the study due to identified pathology – the remaining 53 eyes (blast exposed, $n = 40$; control $n = 13$) underwent blast or control overpressure treatment with peak static pressure ranging from 7 to 22 psi (48 to 152kPa) and post-blast histopathological examination.

As anticipated, increased blast energy was associated with more severe injury. Pathology was described using terminology consistent with the Birmingham Eye Trauma Terminology System with the majority of injuries being described as lamellar in nature. Pathology was divided into three zones: external surface (zone 1); anterior segment (zone 2); and internal posterior segment (zone 3). A unique pattern of closed globe injuries arose following blast with zones 1 and 3 being more susceptible to injury at higher blast pressures and zone 2 sustaining injuries across the range of pressures. Common injuries across all pathology zones included angle recession, cyclodialysis, zonular dehiscence, retinal detachment and scleral delamination – pathology similar to what is observed in clinical populations following blast injury.

The results of this study contribute to the overall understanding of the anatomic consequences of primary blast exposure and provide foundational knowledge for future research using both animal and computational blast models. There is a push for the development and validation of computational models of ocular trauma both to elucidate the mechanisms of blast injury and to test effectiveness of protective eyewear. The authors note limitations for consideration, including the use of postmortem tissue, which may be more susceptible to damage during tissue preparation and testing. Inclusion of the pre-blast examination strengthened the conclusion that the injuries were a result of the primary blast wave and not preexisting, confounding pathology. An additional strength was the comprehensive methods used for histopathological examination. Animal models such as these allow for isolation of the primary shock wave and its effects from any secondary, tertiary or quaternary effects of blast exposure in a controlled laboratory environment; however, like all non-human animal studies, one must be somewhat cautious when extrapolating the results to humans where blast injuries rarely occur in isolation or in a controlled environment.

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Because keratoconus has direct implications for force readiness and is a potentially career-ending diagnosis for Service members, CXL, if proven a valid, effective FDA-approved treatment option, may change the need for the current contraindicated treatments (e.g., contact lenses, corneal surgery), thereby extending a Service member's career. Because CXL with riboflavin is not recognized by the military as a valid treatment option as it is a relatively new, non FDA-approved procedure, there are no official DoD policies regarding corneal cross-linking. The long-term results on future corneal health for patients who undergo CXL early in life remain unknown; therefore, further clinical investigation would greatly benefit individuals with keratoconus. The DoD continues to monitor the progress of clinical trials and advancement of CXL as a therapy given its potential impact on Service members with keratoconus.

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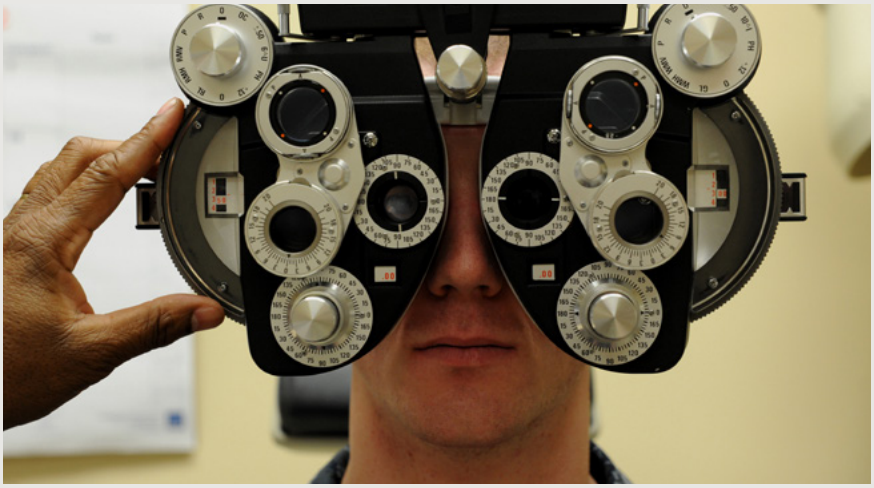
BRIEF REVIEW

ARGUS II RETINAL PROSTHESIS IMPROVES CLINICAL OUTCOMES IN PATIENTS WITH RETINITIS PIGMENTOSA

Rizzo, S., Belting, C., Cinelli, L., Allegrini, L., Genovesi-Ebert, F., Barca, F., di Bartolo, E. (2014). The Argus II Retinal Prosthesis: Twelve-Month Outcomes from a Single Study Center. American Journal of Ophthalmology, 157 (6), 1282-90.
http://www.ncbi.nlm.nih.gov/pubmed/24560994



In their recent report published in the American Journal of Ophthalmology, Stanislao Rizzo et al. (2014) evaluated the safety and efficacy of the Argus II Retinal Prosthesis System in six patients with retinitis pigmentosa (RP) with visual acuity no better than light perception. Retinitis pigmentosa is characterized by degeneration of the photoreceptors but preservation of the inner retinal cells. The epi-retinal Argus prosthesis was recently FDA-approved for marketing in the U.S. and is the only approved prosthetic system for vision restoration. It works by directly stimulating the unaffected inner retinal cells, which leads to the activation, via the optic nerve, of the visual cortex, allowing a patient to perceive spots of light.

Visual function was assessed for 1 year postoperatively in patients fitted with the Argus II. Square localization and direction of motion testing were conducted at baseline, 3, 6 and 12 months and Goldmann visual field testing was performed at baseline and 12 months. Additionally, optical coherence tomography (OCT) images were obtained at 1 week post-surgery to ensure proper positioning of the device. One patient withdrew from the study.

No serious adverse events such as endophthalmitis or retinal detachment occurred; however, one patient experienced elevated intraocular pressure and another had a moderate choroidal detachment the day after surgery. The device remained well-positioned with fully functioning electrodes throughout the course of the 12 months. Performance on the square localization and direction of motion tasks improved in four and three of the five patients, respectively, and Goldmann visual field testing improved in all five patients.

The results of this study, though limited by the small sample size and crude improvements in vision, suggest that the Argus II Retinal Prosthesis System can be safely implanted and well-tolerated in patients with RP. As is true for most clinical studies, the authors note that the study's limited sample size was a direct result of the rigorous patient selection process (e.g., inclusion/exclusion criteria, availability for follow-up) and caution that future studies must take into consideration patient selection to maximize patient compliance with the rigorous follow-up testing schedule necessary for long-term tracking of clinical outcomes. Significant advances and evolution of the technology are required before the Argus II Retinal Prosthesis System proves to provide a positive impact on quality of life.

WORLDWIDE OCULAR TRAUMA CALL

VALSALVA-RELATED PREMACULAR HEMORRHAGE

Summary of a Worldwide Ocular Trauma Video Teleconference

During a recent VCE Worldwide Ocular Trauma Video Teleconference (WWOT VTC), a case of Valsalva-related premacular (subhyaloid) hemorrhage secondary to weight lifting was presented. While weight lifting, a known cause of this type of hemorrhage, is a common activity in the military population, premacular hemorr hage is rarely reported. Premacular hemorrhage can significantly impair visual acuity, particularly if the hemorrhage is localized over the macula. Young, healthy individuals can develop these types of hemorrhages associated with Valsalva-induced maneuvers (e.g., coughing, vomiting, weight lifting); additional underlying etiologies may include increased intravascular pressure and resistance to ocular venous outflow that will cause bleeding from capillary leakage or vascular rupture.[1-4] Most frequently in premacular hemorrhage, blood accumulates in the macular or perimacular areas resulting in sudden and painless loss of

BRIEF REVIEW

MOBILE APP HIGHLY ACCURATE AND EFFICIENT AT CALCULATING SUPERIOR VISUAL FIELD LOSS

Maamari, R.N., D'Ambrosio, M.V., Joseph, J.M., Tao, J.P. (2014). The efficacy of a novel mobile phone application for Goldmann ptosis visual field interpretation. Ophthal Plast Reconstr Surg, 30, 141-145.
http://www.ncbi.nlm.nih.gov/pubmed/?term=24481509

Visual field (VF) testing is commonly included in the preoperative workup for individuals undergoing upper eyelid lifting surgery. To inform their coverage ruling, most insurance companies require formal VF quantification to differentiate cosmetic from functional procedures. For eyelid procedures, superior visual field (SVF) loss is the differentiating criteria, with a 30 percent field loss serving as the typical threshold for medical necessity. Visual fields are measured using a perimeter, most commonly using Goldmann manual kinetic testing or Humphrey automated static testing. Each method has advantages and disadvantages with the most noted limitation of the Goldmann perimetry test being the reliance upon subjective interpretation of the results relative to automated testing. Estimated VF loss can be highly variable and inaccurate with level of the SVF defect often underestimated. To improve accuracy and efficiency and reduce variability of subjective VF testing, a mobile application that calculates SVF defects on the Goldmann VF chart has been developed. With the increasing use of mobile smart phone and portable tablet technology by medical practitioners, it is realistic to envision the adoption and integration of such tools by the eye care community.

In their paper, "The efficacy of a novel mobile phone application for Goldmann ptosis visual field interpretation," Maamari and colleagues developed and systematically tested an iPhone 4S application that calculates the amount of SVF obstruction. The iPhone camera is used to photograph the visual fields and the application calculates the difference in area between the fields. To test the accuracy of the application's calculations, estimated VF loss for 10 standardized VFs were calculated by 14 board certified and fellowship-trained oculoplastic surgeons and by the iPhone application. Exact SVF defect calculations were obtained using the open-source ImageJ software (National Institutes of Health, Bethesda, MD) and mean percent error was calculated for the oculoplastic surgeons and iPhone application estimates. The average of the mean percent error of the oculoplastic surgeons' visual estimates of SVF defects was 19.75 percent whereas the mean percent error for the iPhone application was only 1.98 percent. There was high variability and a statistically significant underestimate of SVF defect within the oculoplastic surgeon group. While this study is limited by the small sample of oculoplastic surgeons included, the results do suggest that a mobile application can be used to reliably and accurately calculate VF loss.

Before being released as a free iPhone application, additional pilot testing and some technological modifications to enhance ease of use (e.g., eliminating the requirement of color-coded VF curves) are required. The authors also intend to develop and release an Android-compatible application. In the meantime, oculoplastic surgeons and others performing eyelid surgery need to consider how they estimate VF loss and make efforts to minimize underestimates and improve accuracy.

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vision. The majority of individuals have their vision return to pre-hemorrhage levels without any visual sequelae, although, there have been rare reports of preretinal scarring associated with persistent hemorrhage. Depending on the location of the hemorrhage, visual complaints or disability will persist until the hemorrhage is resorbed, which may take several weeks to resolve.

This particular case discussion focused on a Service member who was referred for ophthalmic care for complaints of complaints of a unilateral non-traumatic, painless loss of vision with centrally blurred vision with centrally blurred vision, occurring 1 day after heavy weight lifting.

> *"A subhyaloid hemorrhage along the inferotemporal arcade, a small blot of intraretinal hemorrhage superotemporal to fovea and a large subretinal hemorrhage along the inferotemporal arcade consistent with Valsalva retinopathy were revealed."*

Upon examination of the left eye, a subhyaloid hemorrhage along the inferotemporal arcade, a small blot of intraretinal hemorrhage superotemporal to fovea and a large subretinal hemorrhage along the inferotemporal arcade consistent with Valsalva retinopathy were revealed. After a period of observation, the patient was evacuated for further evaluation and treatment using pars plana vitrectomy (PPV) with an internal limiting membrane (ILM) peel with post-operative return of vision. Discussion centered on causes, evaluation and potential management and treatments for valsalva related premacular hemorrhage, particularly for deployed personnel.

The ophthalmic providers reviewing this case on the WWOT VTC recommended approaching this type of injury by first identifying the location of the hemorrhage. If the macula or fovea is involved, then surgical intervention should be considered as the first option. The

BRIEF REVIEW

THE VISIAN IMPLANTABLE COLLAMER LENS FOR CORRECTION OF MODERATE TO HIGH MYOPIA

Igarashi, A., Shimizu, K., Kamiya, K. (2014). Eight-year follow-up of posterior chamber phakic intraocular lens implantation for moderate to high myopia. American Journal of Ophthalmology, 157 (3), 532-9. http:/ www.ncbi.nlm.nih.gov/pubmed/24239774

In the past, spectacles were the only vision correction option permitted in theater, but Service members often did not readily embrace the standard issued glasses. Aside from cosmetic reasons, practical challenges such as breakage, loss and delay in replacement, cleanliness and perceived decreased field vision contributed to resistance of wearing glasses in the field. Today, individuals have several alternatives to spectacles including refractive laser surgery options (e.g., LASIK, PRK) and in cases of moderate to high myopia, phakic intraocular lens (pIOL) implants—importantly, contact lenses are still prohibited in the field. Phakic intraocular lens implants are often the preferred method of treatment for individuals who are not candidates for excimer laser correction, typically because of their corneal anatomy (e.g., too thin) and high level of nearsightedness; however, given the potential for complications secondary to lens implants, longitudinal studies are needed to ascertain long-term outcomes of pIOLs. The Visian Implantable Collamer Lens (Visian ICL; STAAR Surgical, Nidau, Switzerland) is one of two pIOLs that are FDA-approved for treatment of myopia in the U.S.

In their study published in the American Journal of Ophthalmology, Igarashi et al. (2014) report the long-term safety, efficacy, predictability and stability of ICL implantation in 41 patients with moderate to severe myopia (–4.00 to –15.25 diopters). The ICL was implanted in patients who were then followed for 8 years. This was the first study of its kind to assess ICL's clinical outcomes in myopic patients over such a long follow-up period.

After 8 years, 39 percent of eyes had no change in post-operative corrected distance visual acuity and 34 percent of eyes actually gained a Snellen line. 87.8 percent and 73.2 percent of the eyes had uncorrected distance visual acuity of 10/20 and 20/20, respectively; 68.3 percent and 85.4 percent of eyes were within 0.5 D and 1.00 D, respectively, of targeted correction. Changes in endothelial cell density and axial length were observed at year 8; however, the degree of cell loss and axial elongation were less pronounced than previously reported by others. No vision-threatening complications occurred during the entire follow-up period, although two eyes did develop symptomatic cataracts at year 8.

The results indicate that use of the Visian ICL was successful at correcting moderate to high myopia and may be a viable option for vision correction in individuals with contraindications to laser surgery. However, the long-term intraocular health effects for individuals who receive ICLs early in life remains unknown. Additionally, similar long-term follow-up studies of military personnel treated with with ICLs are needed.

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consensus was that both the evacuation and surgical procedure used in this particular case (PPV-ILM) were the best care coordination and treatment options. In the instance where there is no macula or fovea involvement, the group concluded that a non-surgical "watch and wait" approach is acceptable. The group also discussed the use of Nd: YAG laser to convert the subhyaloid heme into a vitreous hemorrhage that can then be

"The consensus was that both the evacuation and surgical procedure used in this particular case (PPV-ILM) were the best care coordination and treatment options."

absorbed – consensus was that YAG disruption is a less desirable approach in light of the advances in small gauge vitrectomy, which have made it the preferred treatment option. Additionally, consensus included that in non-surgical instances, allowing a 1 to 2 week window for observation is appropriate, especially within an in-theater setting where resources are limited; however, if visual complaints or disability persist, then evacuation for definitive treatment would be necessary.

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BRIEF REVIEW

OPHTHALMIC EDUCATION IN MEDICAL SCHOOL CURRICULUM ON THE DECLINE

Shah, M.J., Knoch, D., Waxman, E. (2014). The state of ophthalmology medical student education in the United States and Canada, 2012 through 2013. Ophthalmology, 121 (6), 1160-3.
http://www.ncbi.nlm.nih.gov/pubmed/?term=24518616

A thorough eye exam provides invaluable information about the eye and visual system and because the optic nerve and retina are extracranial extensions of the brain, it also provides information on the state of brain health. The eye exam is an important facet in the diagnosis and follow-up care of many systemic diseases such as diabetes, hypertension, thyroid disease, HIV and leukemia. Medical school curricula should optimally, therefore, include comprehensive study and understanding of the eye in the focus on holistic health care. However, this is increasingly not the case; between 1974 and 1979 ophthalmology training hours dropped from 25 to 22 and from 2000 to 2004 the percentage of schools requiring an ophthalmology rotation dropped from 68 percent to 30 percent.

To determine if this downtrend has continued, Shah and colleagues conducted an electronic and telephone survey of medical school course directors to assess the current state of ophthalmology medical student education at 135 Association of University Professors of Ophthalmology (AUPO) member institutions in the U.S. and Canada, 30 U.S. osteopathic medical schools and 40 U.S. and Canadian non-AUPO-affiliated allopathic medical schools

The survey results showed that preclinical instruction in ophthalmoscopy and the basic eye exam were part of the educational program at 96, 87 and 18 percent of AUPO-affiliated, osteopathic and non-AUPO-affiliated schools, respectively. Elective ophthalmology rotations were offered at 100 percent of AUPO-affiliated and osteopathic schools and 87 percent of non-AUPO-affiliated schools. However, only 18 percent of the AUPO-affiliated, 0 percent of osteopathic and 14 percent of non-AUPO-affiliated schools had required rotations in ophthalmology – a decrease from 2004. More aggressive advocacy by ophthalmic organizations is required to reverse this decline.

The decline in ophthalmic education at the medical school and undergraduate school levels has important implications for those entering primary care-related fields and emergency medicine, as these physicians often represent the first line of medical care and are positioned to serve as 'gate keepers," responsible for making referrals for specialty care, including ophthalmology. It is pertinent that non-ophthalmologists have a foundation and working knowledge of the visual system, particularly ophthalmic disease, to maximize their recognition of suspected eye disease and subsequent referral of patients for specialty ophthalmic care. Additionally, the lack of exposure to ophthalmology during the early years of medical training may result in fewer medical students pursuing ophthalmology and its sub-specialties as a career. While not discussed by the authors, high-fidelity simulation technology may provide an avenue for closing this educational gap, although there remains the need for a comprehensive, standardized simulation curriculum throughout the course of medical education, from medical school through residency and fellowship training. While the field of ocular simulation (e.g., virtual/augmented reality, physical trainers, gaming) lags behind other major medical fields, recent advances in simulation technology are allowing for the greater incorporation of ocular simulation trainers into the educational curriculum.

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